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Unpacking the myth between increased government initiatives and reduced selling of dead live stocks in China: An approach towards exploring hidden danger of zoonotic diseases

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ABSTRACT

Prohibiting the unsafe sale of livestock that have died in production and harmlessly disposing of them are key measures to control and prevent outbreaks of zoonotic diseases and exert a great significance for maintaining meat-derived food and public health safety. However, under the strict implementation of governmental initiatives, some farmers still choose to sell dead livestock unsafely in developing countries such as China, Brazil, Mexico, and Kenya, which have become an important hidden danger in preventing and controlling zoonotic diseases. Based on data from 496 pig farmers in Hebei, Henan, and Hubei, China, the Double Hurdle Model was employed to explore the impact of governmental initiatives on the willingness and proportion of dead pigs sold unsafely by farmers. Besides, based on the heterogeneity of organization participation and breeding scale, the impact of governmental initiatives on different scale farmers' unsafely selling behaviors is also discussed. The results showed that the harmless disposal subsidy significantly reduces farmers' willingness to unsafely sell dead pigs (SW, RC = −0.0666, and SE = 0.0261). Still, the impact on the proportion is weak (SP, RC = −0.0502, and SE = 0.0474). Though the effect of supervision punishment is greatly weakened (SW, RC =−0.0381, and SE = 0.0324; SP, RC = −0.0204 and SE = 0.0263), it can significantly enhance the effect of harmless disposal subsidy by creating a good law-abiding environment (SW, RC = −0.1370, and SE = 0.0374; SP, RC = −0.0820, and SE = 0.0431). Governmental initiatives have an undue impact on the unsafe sale of dead livestock by farmers participating in cooperatives. The effects of these measures on different scale farmers' unsafe sale of dead pigs are highly heterogeneous. In addition, the study also found that food and public health safety risk perceptions are important endogenous drivers for curbing farmers selling dead pigs. This research can also provide important inspiration for other countries. The government should raise farmers' risk perception level of food and public safety, optimize governmental initiatives, play the key role of cooperative organization, increase the proportion of dead pigs harmlessly disposed of, and finally eliminate new hidden dangers in the prevention and control of zoonotic diseases.

1. Introduction

Like manure waste, carcass waste mainly composed of dead livestock caused by various infectious diseases or natural disasters is an inevitable waste produced during breeding livestock [1,2]. In 2018, the Food and Agriculture Organization of the United Nations announced that due to the outbreak of zoonotic infectious diseases, the average mortality rate of dead livestock diseases worldwide is 6–12%, and developing countries generally having a higher mortality rate are weak in coping with the prevention and control of zoonotic infectious diseases [3]. Zoonotic diseases such as Anthrax, Brucella, and foot-and-mouth disease not only bring devastating disasters to the livestock production, but also increase residents' medical expenditures and threaten whole human health, which the SARS has confirmed in 2003 and the current COVID-19 [4–6]. Although the spreading rules of zoonotic diseases are very complex, meat products that carry bacteria or viruses are an important driving factor causing the spread of zoonotic diseases [7–9]. Besides, countries in the world, especially developing countries, such as China, Brazil,

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Mexico, and Kenya, and other mainstream media often expose the flow of livestock, died during production, before slaughter, into the market, and generally believe that this is a difficult and important hidden danger for the prevention and control of zoonotic infectious diseases [10–13]. Some scholars hold that if dead livestock is unsafely sold by farmers and enter butcher shops, markets, and Internet shopping, they will seriously threaten the safety of meat-borne food and even cause major outbreaks of zoonotic diseases [14,15].

Due to the differences in historical origins and cultural ideas and socio-economic conditions, most of the countries experience great differences in their research on methods of dealing with dead livestock, and there are three main approaches or measures around the world. The first is based on animal welfare protection. Some scholars believe that animals have the same rights that humans deserve and should be properly arranged after they die, such as building a cemetery [16–18]. The second is designed for resource reuse. Some scholars assumed that industrial oil extraction technology is an ideal disposal technology, which should be widely adopted in the disposal of dead livestock for clean production [19]. The third is aimed at harmless disposal, which mainly refers to eliminating pathogens that may be carried by dead livestock through deep burial and incineration [20,21]. Although there are some differences in the methods and technologies for disposing of dead livestock, the international community generally believed that the most basic principles and minimum requirements for disposing of dead livestock are to prevent dead livestock from entering the market and eliminate the pathogens they carry, with particular emphasis on maintaining food and public health safety [22,23].

Source control during breeding and process control during transportation, slaughter, and sales processes are the main measures to restrict the flow of dead livestock into the market. An important gateway system for process control is the inspection and quarantine system for livestock meat products. Nevertheless, dead livestock resulting from a series of infectious diseases are produced in a small amount during transportation and slaughter. Additionally, this system only conducts random inspection of meat produced in batches, and a small number of dead livestock carrying pathogens are likely to be hidden outside the sampling system [24,25]. The risk of dead livestock entering the market has been relatively high.

Therefore, how to strengthen source control, restricting farmers' unsafe sale behavior, has become the focus of academic attention. Farmers naturally have the advantage of dead livestock information. They are more concealed in selling dead livestock to merchants to pursue short-term economic profit, which has also brought greater difficulties for government governance. So the unsafe sales of dead livestock mainly mean that farmers sell dead livestock to illegal traders at a low price, and the trader illegally processes and sells dead livestock products. Moreover, the unsafe sale of dead livestock has a strong negative external effect. Government intervention is the main measure to control farmers' unsafe sales of dead livestock, mainly including imperative measures, such as supervision punishment, incentive measures, such as subsidies, etc. In the last few decades, these measures have played an important role in blocking the smooth entry of dead livestock into the market chain [26,27]. However, according to the World Organization for Animal Health (OIE) report, since 2018, Poland, Russia, and China, and other countries have reported 3797 African swine fever outbreaks, and the unsafe sale of dead pigs by farmers is an important factor influencing the outbreak and spread of African swine fever [28].

China is the leading livestock breeding country and the biggest farming pig country in the world. At the same time, China is also the world's major pig meat consumer. In recent years, with the implementation of strengthening and benefiting agriculture policies, the pace of large-scale raising pig has accelerated, regional layout advantages are prominent, and product quality has been steadily improved [29]. The pig industry has played an important role in ensuring the effective supply of livestock products and meat-based food safety. However, the level of scientifically farming pigs in China is generally low, and farmers are not enthusiastic about building standardized farms [30]; the ability to prevent and control epidemics is weak, pig mortality has remained at 8%, and 60 million pigs die each year [31]. To prevent farmers from unsafely selling dead pigs, the Chinese government has carried out two main initiatives. The first is the supervision and punishment policy. The four-level supervision system composed of province, city, county, and township was established. County-level livestock, health, forestry, and market supervision departments form an enforcement team to supervise key areas and populations from time to time. Grid management is implemented in these areas. Once illegal acts are found, administrative penalties will be given in accordance with the related laws. The second is the subsidy policy, that is, if the dead pigs are harmlessly disposed of by farmers through deep burial and incineration, etc., farmers will be subsidized 80 yuan per head. However, lots of media often report cases about dead pigs unsafely sold by farmers, and some dead pig product has entered various markets. Meanwhile, there are few academic and empirical studies on the influencing factors on the unsafe sales of dead pigs by farmers. So, have the governmental initiatives in which the government have invested a lot of human and financial resources ever been operating inefficiently? What are the other factors that affect farmers' unsafely sale? Answering these questions constitutes the main purpose of the study.

According to those mentioned above, based on data from 496 pig farmers in Hebei, Henan, and Hubei, China, the Double Hurdle Model was adopted to analyze the impact of governmental initiatives on the willingness and proportion of dead pigs unsafely sold by farmers. Moreover, considering the heterogeneity of organization participation and breeding scale, the impact of governmental initiatives on different farmers' unsafe sale of dead pigs will also be discussed.

2. Data and method

2.1. Data sources

The study data are obtained from the field survey of 9 districts in Hebei, Henan, and Hubei provinces conducted by the research team from July to August 2018 (Fig. 1). In September 2019, we conducted a return visit to 24 respondents to supplement and check related data. The selection of the sample area mainly takes into account the following three factors. Firstly, these provinces are intensively pig-raised areas. In 2017, the number of breeding pigs in Hebei, Henan, and Hubei was 35,710, 62,200, and 43,000 million, respectively. The number of dead pigs caused by different infectious diseases was 2.856, 4.976, and 3.400 million. Secondly, since 2013, these provinces have continuously strengthened the supervision punishment of unsafe sale of dead pigs. Meanwhile, technical guidance and subsidy policies are carried out simultaneously to prompt the harmless disposal of dead pigs. Thirdly, some farmers still choose to sell dead pigs are often exposed by the media in these provinces. Thus, the selection of the sample area has good typicality and representativeness.

The data types for this study included questionnaires and interview data. The stratified and random sampling methods were adopted for the questionnaire survey. The specific sampling steps are as follows: randomly selecting 2 to 4 towns in the sample districts, picking out 3 to 5 villages in the towns, and conducting random surveys on farmers engaging in breeding pigs in the villages. The main content of the questionnaire includes the basic information of individual, business, social, and environmental characteristics, as well as farmers' risk awareness, government regulations, and harmless disposal, etc. Around 550 questionnaires were sent out during the survey, and blank or invalid samples were eliminated. Finally, 496 valid samples were obtained, accounting for 90.18% of the total sample. The sample includes 190, 151, and 155 farmers in Hebei, Henan, and Hubei. Moreover, the research team took the form of interviews with the persons in charge of the livestock departments of some districts and towns and obtained a total of 30 interview records, which comprehensively grasp the details

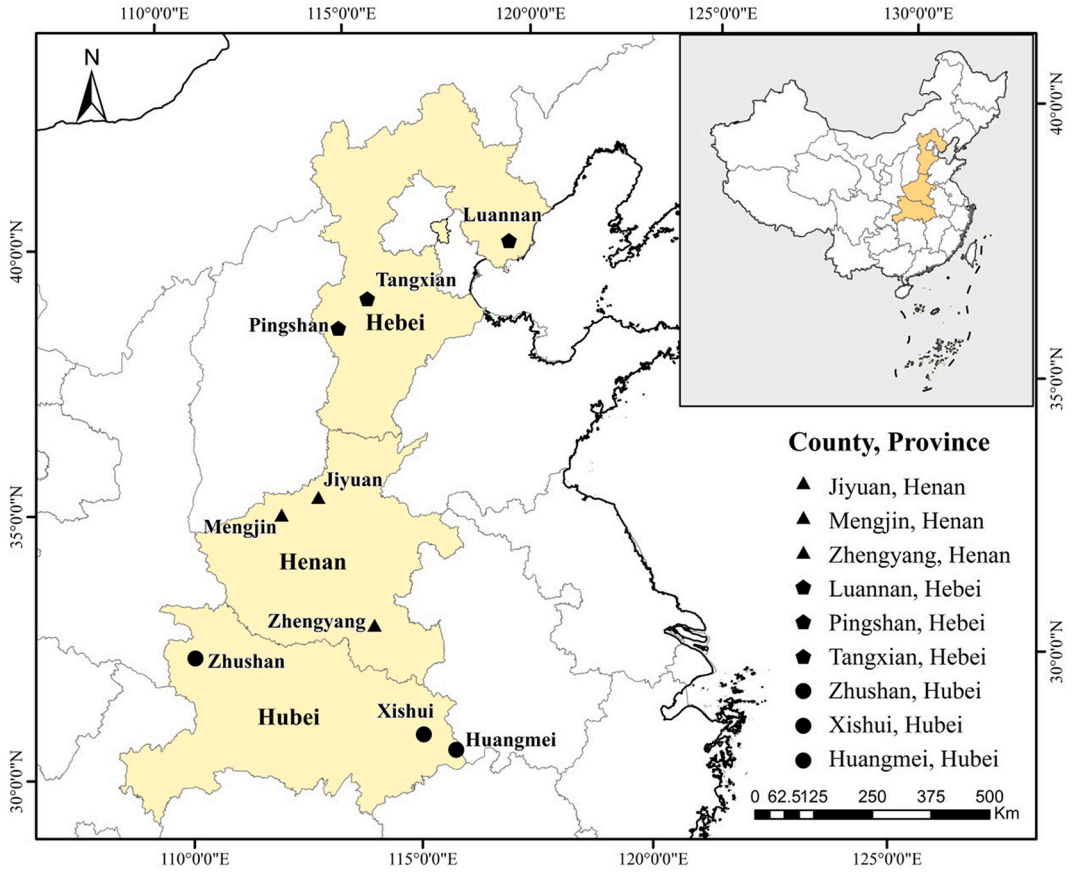

Fig. 1. Distribution of survey areas (Source: National Surveying and Mapping Geographic).

concerning pig industry development, government intervention policies, and the harmless disposal of dead pigs.

It should be noted that during the investigation, the research team considered that farmers might realize that it is illegal to sell dead pigs unsafely so false answers were expected. Accordingly, in addition to the questionnaire, this study obtained key information from the livestock department on the supervision punishment cases of unsafe sale of dead pigs and conducted targeted investigations based on the list of offenders. Of course, these target samples are also randomly selected, and their personal information will not be leaked. Besides, some farmers are recruited to members of the research team, and the social relationship among farmers is strong, making it easier for farmers to get real answers.

2.2. Variable selection

2.2.1. Dependent variable

The dependent variables include whether farmers are willing to unsafely sell dead livestock (after this referred to as selling willingness——abbreviated as SW) and the proportion of dead pigs sold (after this referred to as selling proportion——abbreviated as SP). The corresponding questions in the questionnaire are "Are you willing to sell dead pigs". If the farmer is willing to sell dead pigs, then the assignment is 1; otherwise, the value is 0. In the sample, 161 farmers are willing to sell dead pigs, selling them mainly to traders at a lower price. However, the proportion of dead pigs sold is calculated by the ratio of unsafely sold dead pigs to dead pigs. The questions in the questionnaire are "the number of dead pigs you unsafely sold " and "How many dead pigs were in production last year". Therefore, selling proportion is a numerical continuous variable. Although these numbers may be lower than the actual situation, the research team has adopted the methods mentioned above and tried to reduce the data bias.

2.2.2. Independent variable

Independent variables mainly include governmental initiatives, the policies of supervision punishment, and harmless disposal subsidy. The corresponding information is got by asking the farmer two questions, such as "times of supervision and punishment you have received" and "amount of harmless disposal subsidy you have obtained". Hence, both variables are acted as continuous numerical variables.

Control variable. In addition to governmental initiatives, other factors regarded as control variables may also affect farmers' unsafe sales of dead pigs. Based on related research by Musalia et al. [32] and Si et al. [3], the farmers' characteristics (e.g., gender, age, and education level), family characteristics (e.g., several laborers, political identity), operating characteristics (e.g., breeding scale), risk perception (e.g., food safety risk perception, public health safety risk perception), and environmental conditions (e.g., the distance between farmer and livestock department) were interpreted as control variables. Additionally, regional dummy variables are introduced in the study to control the influence of different location factors on model estimation results. Taking Henan as the control group, two dummy variables were set, "is it located in Hebei" and "is it located in Hubei". The assignment of all variables and descriptive statistics are shown in Table 1.

2.3. Research method

Considering that the dependent variables in this study include selling willingness and selling proportion, the former belongs to discrete binary variables. The latter is treated as a numerical continuous variable. Some studies mainly adopt Probit and Tobit models for estimation, respectively [33,34]. However, the two models cannot make simultaneous estimates of the dependent variable. Other scholars believed that the Heckman model could simultaneously estimate willingness and degree

Table 1
Assignment of variables and descriptive statistics.

Variables	Assignment of variables	Mean	Std. error
Dependent variable			
Selling willingness	Willing = 1, unwilling = 0	0.325	0.107
Selling proportion	The ratio of dead pigs sold unsafely to dead pigs	0.084	0.031
Independent variable			
Supervision punishment	Times of supervision and punishment	4.206	1.024
Harmless disposal subsidy	Amount of harmless disposal subsidy (yuan)	324.534	36.206
Control variable			
Gender	Male = 1, female = 0	0.905	0.176
Age	Actual age (years)	47.625	8.430
Education level	Actual years of schooling (years)	8.225	2.324
Number of laborers	Number of laborers over 16 years old (people)	2.518	1.802
Political identity	If there is a civil servant at home, 1 is assigned; otherwise, the value is 0.	0.218	0.062
Breeding scale	Number of breeding pig (head)	426.250	467.280
Food safety risk perception	Does unsafe sale of dead pigs endanger food safety? (Completely impossible = 1—Completely possible = 5)	3.815	1.165
Public health safety risk perception	Does unsafe sale of dead pigs endanger public health safety? (Completely impossible = 1—Completely possible = 5)	3.205	1.312
Distance between farmer and livestock department	Distance between farmer and livestock department (km)	8.895	4.805
Regional dummy variable			
Is it located in Hebei?	If the farmer is located in Hebei, the value assigned is 1; Otherwise, the value is 0.	0.301	0.401
Is it located in Hubei?	If the farmer is located in Hubei, the value assigned is 1; Otherwise, the value is 0.	0.383	0.386

of behavior [35,36]. However, this model is based on the original assumption that behavior willingness and the degree equation are related. The error of the former equation is often brought into the latter equation, which eventually leads to bias in the estimation results.

Consequently, the Double-Hurdle Model (DHM), is employed to assess the impact of governmental initiatives on farmers' unsafe sale of dead pigs. DHM can not only decompose the decision-making process into two stages of selling willing and proportion but also make a complete decision only when the two stages are established simultaneously [37]. The two-stage equations in DHM are estimated independently, which can avoid endogenous problems between equations. The model is built as follows:

Firstly, whether the farmers are willing to sell dead pigs should be analyzed. The equation constructed is as follows:

$$probit[y_i = 0|x_{1i}] = 1 - \varphi(ax_i) \quad (1)$$

$$probit[y_i > 0|x_{2i}] = \varphi(ax_i) \quad (2)$$

Among them, (1) represents that farmer is not willing to sell dead pigs, (2) represents that the farmer is willing to sell, and x_i represents independent, control, and regional dummy variables, $\varphi(\cdot)$ is the cumulative function of the standard normal distribution, a is the corresponding coefficient to be estimated, and i represents the observation samples.

$$E[y_i|y_i > 0, x_{2i}] = \beta x_{2i} + \eta\lambda(\beta x_{2i}/\eta) \quad (3)$$

where $E(\cdot)$ is the conditional expectation, that is, the selling proportion, $\lambda(\cdot)$ is the inverse Mills ratio, β is the corresponding coefficient to be estimated, and η is the intercepted normal distribution standard deviation.

According to (1), (2), and (3), a log-likelihood function can be established:

$$L = \sum_{y_i}\{ln[1-\varphi(ax_i)]\} + \sum_{y_i}\{ln\varphi(ax_i) - ln\varphi(\beta x_{2i}/\eta) - ln(\eta)\} + ln\{\varphi[(y_i - \beta x_{2i}/\eta)]\} \quad (4)$$

Then, the log-likelihood function value ln$L$ calculated by the maximum likelihood estimation method is finally obtained, and the relevant parameters needed for this study also are obtained.

3. Results

3.1. Impacts estimated of governmental initiatives

Before analyzing the impacts of governmental initiatives, multi-collinearity was checked to reduce biased results. The main method of the test is to select any of the variables as the dependent variable and the other variables as the independent variables for linear regression, and then to determine whether there is multi-collinearity by identifying the VIF (Variance Inflation Factor) value. If the VIF value is greater than 10, severe multi-collinearity is considered to be present. The results show that the maximum value of VIF is 2.230, the minimum value is 1.106, and the average value is 1.518. Due to space limitations, the VIF value estimation results of gender as the dependent variable and other variables as independent variables are given in Table 2.

To estimate the effect of governmental initiatives on the unsafe sale of dead pigs, firstly governmental initiatives are introduced into the DHM (Model 1). Then the interaction term of governmental initiatives is included in the equation (Model 2). The regression results are shown in Table 3. According to the estimation results in Model 1, supervision punishment fails to restrain farmers from unsafely selling dead pigs(SW, RC = −0.0381 and SE = 0.0324; SP, RC = −0.0204, and SE = 0.0263), the possible explanation is that the farmers have the inherent advantages of the information on dead pigs, and there is a serious information asymmetry between the farmers and livestock department on the dead pigs' information [38,39]. Both the concealment of unsafe sale and the illegal transaction is strong, indicating that the underground trading market chain of dead pigs still exists. In addition, there is less law enforcement staff in the livestock department resulting in weak regulatory forces [40]. Accordingly, the direct effect of supervision punishment implemented by the government is more invalid.

According to Model 1, a harmless disposal subsidy can significantly

Table 2
Multi-collinearity diagnosis results.

Dependent variable	Independent variable	Multi-collinearity diagnosis	
		VIF value	Expansion factor
Gender	Selling willingness	2.205	0.454
	Selling proportion	1.067	0.937
	Supervision punishment	1.350	0.741
	Harmless disposal subsidy	2.012	0.497
	Age	1.835	0.545
	Education level	1.305	0.766
	Number of laborers	1.106	0.904
	political identity	2.230	0.448
	Breeding scale	1.802	0.555
	Food safety risk perception	1.202	0.832
	Public health safety risk perception	1.116	0.896
	Distance between farmer and livestock department	1.620	0.617
	Is it located in Hebei?	1.201	0.833
	Is it located in Hubei?	1.205	0.830
	Mean	1.518	

Table 3
Estimation results of governmental initiatives impact.

Independent variables	Model 1		Model 2	
	Selling willing	Selling proportion	Selling willing	Selling proportion
Supervision punishment	−0.0381 (0.0324)	−0.0204 (0.0263)	−0.0241 (0.0306)	−0.0448 (0.0385)
Harmless disposal subsidy	−0.0666** (0.0261)	−0.0502 (0.0474)	−0.0356* (0.0192)	−0.0106 (0.0072)
Supervision punishment*Harmless disposal subsidy			−0.1370*** (0.0374)	−0.0820* (0.0431)
Gender	0.0930** (0.0388)	0.0518*** (0.0164)	0.0730** (0.0352)	0.0318* (0.0177)
Age	0.0009 (0.0020)	0.0371 (0.0366)	0.0012 (0.0020)	0.0251 (0.0212)
Education level	−0.0205*** (0.0079)	−0.0042 (0.0138)	−0.0165*** (0.0048)	−0.0045 (0.0122)
Number of laborers	−0.0102 (0.0266)	0.0236 (0.0191)	−0.0142 (0.0230)	0.0156 (0.0193)
Political identity	−0.0966** (0.0451)	−0.0478** (0.0196)	−0.0746** (0.0350)	−0.0421* (0.0222)
Breeding scale	0.0001 (0.0005)	0.0130 (0.0109)	0.0012 (0.0025)	0.0122 (0.0119)
Food safety risk perception	−0.0315*** (0.0092)	−0.0427*** (0.0158)	−0.0265*** (0.0072)	−0.0467*** (0.0147)
Public health safety risk perception	−0.0135* (0.0079)	−0.0662* (0.0345)	−0.0155* (0.0089)	−0.0672* (0.0376)
Distance between farmer and livestock department	0.0070 (0.0374)	0.0001 (0.0020)	0.0014 (0.0302)	0.0011 (0.0025)
Is it located in Hebei?	0.0005 (0.0021)	0.0153 (0.0161)	0.0011 (0.0022)	0.0103 (0.0142)
Is it located in Hubei?	0.0001 (0.0001)	−0.0120 (0.0256)	0.0004 (0.0015)	−0.0320 (0.0276)
Chi-square value	86.34***		86.59***	
Log-likelihood	−105.023		−102.091	

Note: *, **, and ***represent significance at the 10%, 5%, and 1% probability levels, respectively. Values outside the parentheses represent the regression coefficient (after this referred to RC) values. Values in parentheses represent the standard error of robustness (after this referred to SE).

reduce farmers' willingness to sell dead pigs (SW, RC = −0.0666, and SE = 0.0261), but it does not significantly affect the selling proportion (SP, RC = −0.0502 and SE = 0.0474). The harmless disposal subsidy can disperse the cost of dead pigs produced, stabilize the economic benefits of the breeding pig, and continuously increase the enthusiasm and initiative of farmers to implement harmless disposal such as deep burial or incineration, etc. [41,42]. Hence, farmers' willingness to sell dead pigs continues to decline. However, per dead pig is subsidized 80 yuan, which is much lower than the price of the dead pig. It can be learned through investigation that 100 kg of dead pigs is 300 to 500 yuan. Under the cost-benefit trade off, the harmless disposal subsidy is difficult to encourage farmers to reduce selling proportion.

According to the estimation results in Model 2, the interaction term of governmental initiatives has a negative and significant effect on the willingness (SW, RC = −0.1370, and SE = 0.0374) and proportion (SP, RC = −0.0820, and SE = 0.0431) of unsafe sales, further suggesting that the interaction can effectively restrict the unsafe sale of dead pigs by farmers. A possible explanation is that a good environment for the rule of law can ensure the effective operation of government policies [43]. Though the direct impact of supervision punishment is weak, 85.45% of the farmers interviewed believe that the supervision punishment can create a good law-abiding atmosphere, which is still effective for the government to implement the harmless disposal subsidy policy thoroughly. Therefore, the willingness to sell dead pigs is reduced, the policy of harmless disposal subsidy is promoted, and it finally ensures the efficient implementation of harmless disposal subsidy policy.

Additionally, according to Model 2, the head of the household's gender exerts a significant and positive effect on the unsafe sale of dead pigs by farmers (SW, RC = 0.0730, and SE = 0.0352; SP, RC = 0.0318, and SE = 0.0177), indicating that compared with female heads, male heads are more at risk of selling dead pigs. Education level (SW, RC = −0.0165 and SE = 0.0048), political identity (SW, RC = −0.0746 and SE = 0.0350; SP, RC = −0.0421 and SE = 0.0222), food safety (SW, RC = −0.0265 and SE = 0.0072; SP, RC = −0.0467 and SE = 0.0147), and public health safety risk perceptions (SW, RC = −0.0155 and SE = 0.0089; SP, RC = −0.0672 and SE = 0.0376) can restrain the unsafe sale of dead pigs by farmers. In particular, if farmers have received a good education, they will be more likely to have law knowledge of disposing of dead pigs, uphold a stronger sense of compliance, and express a lower willingness to sell dead pigs. The unsafe sale of dead pigs is the initial link for dead pigs entering the market, which will inevitably threaten meat-based food safety. If farmers have a high level of food safety awareness, they may also be potential consumers and inclined to choose the harmless disposal of dead pigs. The unsafe sale is likely to cause the rapid spread of pathogens carried by dead pigs, and the outbreak is a serious threat to the development of the pig industry. Thus, it is a rational choice for farmers to reduce the selling of dead pigs. Food and public health safety risk perceptions have become the most important endogenous drivers of farmers' behavior choices.

3.2. Moderating effects based on organizational participation

The organization's participation is an institutional arrangement for farmers to optimize risk strategies and mitigate risk shocks in the framework of neoclassical economics, transaction cost economics, and game theory [44]. Farmers' participation in operating or non-profit organizations such as cooperatives and industry associations can reduce the risks of technology adoption and market operation and achieve economies of scale and reduce transaction costs [45,46]. Additionally, farmers are also subject to organizational rules and regulations; if they violate the legal operating provisions, which are written in the organization's rules and regulations, they are likely to lose their organizational qualifications and face more severe market risks [47]. Zhou [48] and Knight-Jones [49] believed that joining cooperatives and other organizations positively and significantly impacted farmers' implementation of environmentally-friendly agricultural production. However, other scholars assumed that cooperatives have the trend of shareholdings and without shelling. The impact of cooperatives on farmers' behavior is not obvious [50,51]. Therefore, whether organization participation can affect the behavior of farmers is still controversial. In the study, the farmers participating in cooperatives or breeding associations are used as the classification criterion. The group regression model is employed to explore further the impact of governmental initiatives on farmers' unsafe sale of dead pigs. In the sample, 278 farmers participated in cooperatives or breeding associations, and 218 did not join any organization. Table 4 gives the results of group regression estimation, which can be explained as follows.(See Table 4.)

Compared with Model 2, in the group of the farmer not participating in the organization, the effects of supervision punishment (SW, RC = −0.0786, and SE = 0.0641; SP, RC = −0.0858, and SE = 0.0603), harmless disposal subsidy (SW, RC = −0.1522, and SE = 0.0845; SP, RC = −0.0972, and SE = 0.0795), as well as the interaction term (SW, RC = −0.1625, and SE = 0.0755; SP, RC = −0.0866, and SE = 0.0454) did not change significantly apart from the regression coefficients. However, in the group of farmers participating, supervision punishment (SW, RC = −0.0926, and SE = 0.0501; SP, RC = −0.0652, and SE = 0.0349), harmless disposal subsidy (SW, RC = −0.0922, and SE = 0.0401; SP, RC = −0.0878, and SE = 0.0462), as well as the interaction term (SW, RC =

Table 4
Impact estimated based on the heterogeneity of organizational participation.

Explanatory variables	organizational participation (Model 3)		Not organizational participation (Model 4)	
	Selling willing	Selling proportion	Selling willing	Selling proportion
Supervision punishment	−0.0926* (0.0501)	−0.0652* (0.0349)	−0.0786 (0.0641)	−0.0858 (0.0603)
Harmless disposal subsidy	−0.0922** (0.0401)	−0.0878* (0.0462)	−0.1522* (0.0845)	−0.0972 (0.0795)
Supervision punishment*Harmless disposal subsidy	−0.1521*** (0.0454)	−0.1202*** (0.0401)	−0.1625** (0.0755)	−0.0866* (0.0454)
Control variable	Control		Control	
Regional dummy variable	Control		Control	
Sample	278		218	

Note: *, **, and ***represent significance at the 10%, 5%, and 1% probability levels, respectively. Values outside the parentheses represent the regression coefficient values. Values in parentheses represent the standard error of robustness.

−0.1521, and SE = 0.0454; SP, RC = −0.1202, and SE = 0.0401) has an active and significant promotion for farmers' unsafe sale of dead pigs. The possible explanations are that on the one hand, to save administrative resources, the livestock department does not adopt a direct supervision strategy but strengthens its propaganda, guidance, and restraint to members through organizations such as cooperatives or breeding associations. In other words, various organizations are responsible for supervising members, and the livestock department only supervises a limited number of organizations. These organizations have a strong binding effect on members through the internal interest connection mechanism [52,53]. On the other hand, cooperative organizations provide policy promotion, technical assistance, and centralized removal for the harmless disposal of dead pigs [54]. The cost of harmless disposal is lower, thereby further releasing the incentive effect of the harmless disposal subsidy policy.

3.3. Estimated impacts based on the heterogeneity of breeding scale

Considering the heterogeneity of the economic and social structures embedded in different scale farmers, existing studies on the behavior of farmers have also mostly regarded breeding scale as a classification criterion. Generally, the larger is the farming scale, the more standardized the farmers' behavior [24,55]. However, some scholars believe that the farming scale could not fully explain farmers' production and environmental behavior. Farmers' optimal behavior choices are not directly proportional to the breeding scale [56]. Hence, it is necessary to verify further the relationship between the breeding scale and the unsafe sale of dead pigs by farmers. Taking the annual production as the dividing standard, those with less than 50 heads are classified as free-range farmers, and the main type is family breeding. Those with 50–500 heads are called professional farmers, and cooperatives are the primary organization type. Those with more than 500 heads are regarded as large-scale farmers, and the main organization form is enterprise. In the sample, there are 158 free-range farmers, 190 professional farmers, and 148 large-scale farmers. Models 5 to 7 show the effect of governmental initiatives on the unsafe sale of different scale farmers. (See Table 5.)

The results show that (1) supervision punishment has less impact on unsafe sales of dead pigs by the free-range farmer (SW, RC = −0.0306 and SE = 0.0421; SP, RC = −0.0252 and SE = 0.0330), harmless disposal subsidy can only reduce free-range farmer's willingness to sell dead pigs(SW, RC = −0.0324, and SE = 0.0175; SP, RC = −0.0472, and SE = 0.0369), and the effect of interaction terms on free-range farmers' behavior is weak (SW, RC = −0.0525, and SE = 0.0459; SP, RC = −0.0212, and SE = 0.0481). Overall, governmental initiatives are ineffective for restricting free-range farmers. The unsafe sale of dead pigs by free-range farmers is a blind spot for government governance, and they should also become the focus of future governance. (2) Compared with the overall effect in Model 2, the impact of supervision punishment (SW, RC = −0.0686, and SE = 0.0552; SP, RC = −0.0601, and SE = 0.0403) and harmless disposal subsidy (SW, RC = −0.1125, and SE = 0.0601; SP, RC = −0.0671, and SE = 0.0722) on professional farmers is roughly equivalent. Professional farmers are an intermediate form of transition from free-range to large-scale farmers. They are also the main body of a current breeding pig. Their behavior choices and trends are more representatives of the pig farming industry. (3) Compared with the overall effect, supervision punishment can significantly reduce the selling proportion of large-scale farmers (SP, RC = −0.0458, and SE = 0.0193). Large-scale farmers operate mainly in raising pigs and are the key targets of livestock department supervision. Moreover, the harmless disposal of dead pigs is linked to preferential policies such as insurance and taxation; that is, if farmers are punished for unsafe sales of dead pigs, they are likely to lose government support policies. Consequently, apart from other factors, supervision punishment has become an important factor in pushing large-scale farmers to reduce dead pigs' unsafe sales. Overall, the impacts of governmental initiatives on the unsafe sale of dead pigs of different scale farmers are highly heterogeneous.

4. Discussions

There is a serious information asymmetry about dead pig information between the government and farmers. Farmers' unsafe sale of dead pigs has become a crucial hidden danger leading towards zoonotic diseases and posing a severe threat to meat-borne food and public health safety. Like other countries, China has generally adopted supervision punishment and subsidies in restricting farmers for the unsafe sale of dead pigs. Limited to the concealment of information about dead pigs

Table 5
Estimation results based on different breeding scales.

Explanatory variables	Free-range farmers (Model 5)		Professional farmers (Model 6)		Large-scale farmers (Model 7)	
Supervision punishment	−0.0306 (0.0421)	−0.0252 (0.0330)	−0.0686 (0.0552)	−0.0601 (0.0403)	−0.0586 (0.0463)	−0.0458** (0.0193)
Harmless disposal subsidy	−0.0324* (0.0175)	−0.0472 (0.0369)	−0.1125* (0.0601)	−0.0671 (0.0722)	−0.0922** (0.0445)	−0.0374 (0.0481)
Supervision punishment* Harmless disposal subsidy	−0.0525 (0.0459)	−0.0212 (0.0481)	−0.1425** (0.0655)	−0.0361* (0.0196)	−0.1601*** (0.0421)	−0.0566** (0.0254)
Control variable	Control		Control		Control	
Regional dummy variable	Control		Control		Control	
Sample	158		190		148	

Note: *, **, and ***represent significance at the 10%, 5%, and 1% probability levels, respectively. Values outside the parentheses represent the regression coefficient values. Values in parentheses represent the standard error of robustness.

entering the market and the weak supervision power of the livestock department, typical cases and illegal incidents are mainly reported only by a series of media. Accordingly, the unsafe sale of dead pigs has become the new hidden danger in preventing and controlling zoonotic diseases. Besides, the academic community, in theory, believed that the policy coordination of supervision punishment and subsidy could curb the unsafe sale of dead pigs by farmers, so scholars have little empirical research on this field. Meanwhile, there is very little literature on the interaction relationship between supervision punishment and harmless disposal subsidy. This study also further discusses the effects of the heterogeneity of organizational participation and breeding scale.

In contrast to research by Wang et al. [23], Si et al. [29], and Ferguson et al. [57], this study employed empirical research methods to confirm that if the government only increases the intensity of supervision punishment or increases the amount of subsidies, these measures will be difficult to drive farmers to restrain the unsafe sale of dead pigs. Only when these two types of initiatives cooperate can the combined policy effect be achieved. Additionally, the supervision punishment policy strengthens the effect of subsidy policies by creating a good law-abiding environment, showing the indirect impact of supervision punishment. Our research also found that other factors significantly impact farmers who chose to sell dead pigs unsafely, such as the head of the household's gender, education level, and political identity. How to stimulate the subjective initiative of farmers and encourage them to consciously curb illegal behavior is a matter of general concern to the international community [36,43]. Our research also found that food and public health safety risk awareness is the most crucial endogenous factor to curb farmers' unsafe sales, providing a targeted direction for raising farmers' risk awareness in the future.

Additionally, this study responds to the debates about the effects of organizational participation and breeding scale. Consistent with the research by Zhou [48] and Gardner et al. [58], this study found that if farmers participate in social organizations such as cooperatives, the unsafely selling proportion of dead pigs is significantly reduced, indicating that the rules of organizations such as cooperatives have become an important force to restrict members of supervision, which has provided new ideas for reversing government's regulatory directions. Consistent with Mehmet and Mevlut [24], Pan [55], and Laanen et al. [59], this study found that the larger the scale of farming, the higher the level of standardized farming. Governmental initiatives have a strong impact on the large-scale farmer's unsafe sale of dead pigs. In addition, the results also show that promoting the transition and upgrading of free-range farmers to large-scale farmers is a basic principle for the development of the breeding industry.

The research proposes the following policy recommendations. Firstly, organizations such as the livestock department and industry associations should adopt mobile communication, computer networks, and notifications, etc. to encourage farmers to realize the safety risks caused by the unsafe sale of dead pigs and shoulder corresponding legal responsibilities, finally deepening farmer's food and public health safety awareness, and preventing farmers from selling dead pigs unsafely and other improper disposals. Secondly, improper disposing of dead pigs should be exposed, severe punishment should be imposed on the acquisition and processing of dead pig factories, and criminal responsibility for food safety crimes should be investigated. At the same time, spot checks and random inspections of key groups, links, and areas for the sale of dead pigs are conducted to increase the illegal costs of farmers and expand the scope of harmless disposal supervision. In addition, the harmless disposal subsidy should not be calculated based on the number of heads but based on the weight of dead pigs, while taking into account the type of dead pigs, because weight is a direct reflection of cost input, and the type of dead pigs determines market benchmark price. Thirdly, the government's guidance on the operating system of cooperatives and other organizations should be strengthened, promote the standardized operation of organizations, and fully play an important role of organizations in restricting members from unsafely selling dead pigs.

5. Conclusions

Based on data from 496 pig farmers in Hebei, Henan, and Hubei, China, the Double Hurdle Model was employed to explore the impact of governmental initiatives on the willingness and proportion of dead pigs sold unsafely by farmers. The results showed that incentive measure represented by a subsidy for dead pigs disposed of harmlessly exerts great influence on reducing the willingness of farmers' unsafe sales. Still, there is no great impact of incentive measures on the selling proportion. The imperative measure represented by supervision punishment is difficult to restrain farmers from unsafely selling dead pigs, but its indirect effect can't be denied; that is, the imperative measure can promote the efficient implementation of incentive measures by creating a good law-abiding environment. Consequently, governmental initiatives are inseparable; that is, both supervision punishment and harmless disposal subsidy should be implemented simultaneously. In addition, the study also found that if farmers joined organizations such as cooperatives, their willingness and proportion of unsafely selling dead pigs would remain low. Although the impact of these measures on different scale farmers is highly heterogeneous, it is undeniable that the larger the breeding scale, the stronger the impact of these policies. Moreover, the study also found that food and public health safety risk perceptions are the most important endogenous drivers for holding back farmers' unsafe sales.

Ethics statement

This research, approved by the School of Public Administration, Xi'an University of Architecture and Technology, China, conducted a field survey of farmers' unsafe sale of dead pigs that have died in production. This study has obtained the approval and informed consent of the Ethics Committee of Xi'an University of Architecture and Technology. The questionnaire survey was also authorized by the livestock departments of Hebei, Henan, and Hubei provinces. Meanwhile, the research team strictly respects the rights of animals in the content of the questionnaire and interviews with farmers. The authors ensure that the work described has been carried out following The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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Authors' contribution

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Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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